Scientific paper

Dietary comparison of pike-perch, *Sander lucioperca* (Linnaeus, 1758) and catfish, *Silurus glanis* Linnaeus, 1758 in Sidi Salem dam reservoir (Tunisia)

by

Houda DJAIT (1), Lilia BAHRI-SFAR* (1), Houcine LAOUAR (2), Néjiba MISSAOUI (2)
& Oum Kalthoum BEN HASSINE (1)

Abstract. – Sidi Salem dam (Northern Tunisia) hosts two introduced predatory fish species: the pike-perch, *Sander lucioperca*, and the catfish, *Silurus glanis*. We examined the stomach contents of 162 *S. glanis* and 547 *S. lucioperca* specimens sampled along two years from four different stations in the dam reservoir. Both species were found to feed mainly on teleost fishes, with the cyprinids *Sarmarutilus rubilio* and *Scardinius erythrophthalmus* as the main preys. One species of crustacean and insect larvae were found to be occasionally consumed. The comparison of vacuity index revealed differences only between juveniles and adults of *S. lucioperca* collected in the upstream station during winter. Considering the diet composition, no significant difference was found depending on age, sex, seasons and stations in each species. Finally, the two predators display the same diet.

© SFI
Received: 14 May 2018
Accepted: 14 Feb. 2019
Editor: E. Dufour

Résumé. – Comparaison du régime alimentaire du sandre, *Sander lucioperca* (Linnaeus, 1758), et du silure, *Silurus glanis* Linnaeus, 1758, dans la retenue du barrage de Sidi Salem (Tunisie).

La retenue du barrage de Sidi Salem, en Tunisie, héberge deux espèces carnassières prédatrices, le sandre, *Sander lucioperca* et le silure, *Silurus glanis*. L'examen du contenu stomacal de 162 spécimens de silure et de 547 spécimens de *S. lucioperca* a été effectué durant deux années dans quatre stations. Les deux espèces se nourrissent principalement de cyprinidés *Sarmarutilus rubilio* et *Scardinius erythrophthalmus*. Une espèce de crustacés et des larves d'insectes sont aussi consommées occasionnellement. La comparaison des indices de vacuité montre une différence significative seulement entre les juvéniles et les adultes de sandre de la station amont pendant l'hiver. Aucune différence n'a été observée dans le régime alimentaire, que ce soit suivant l'âge, la saison, le sexe ou la station. Finalement les deux espèces *Sander lucioperca* et *Silurus glanis* ont le même régime alimentaire.

Key words
Sander lucioperca
Silurus glanis
Diet
Trophic overlap
Sidi Salem reservoir
Tunisia

In order to extend local Tunisian freshwater fish communities and create a commercial fishery activity, various European fish species have been introduced into freshwater reservoirs in the 60s and 90s through a Tunisian-German cooperation project (GTZ). The project has significantly enhanced the Tunisian freshwater fisheries (Losse *et al*., 1991). In Sidi Salem reservoir, which is the largest dam in Tunisia, 13 fish species, both native and introduced, were reported in 1990 (Tab. I and references therein), including the pike-perch, *Sander lucioperca* (Linnaeus, 1758), and the catfish, *Silurus glanis* Linnaeus, 1758. These two predator fishes, introduced in 1990, have found optimal conditions for their growth and reproduction in Sidi Salem reservoir (M'hetli, 2001; Djemali, 2005; Boughedir, 2006; Mili *et al*., 2016). For instance, the growth performance of *S. lucioperca* in Sidi Salem reservoir was reported to be better than that observed in Lake Feldberger Haussee in Germany (Wysujack *et al*., 2002). Thus, their population have rapidly grown as evidenced by instant weight biomass estimations using echo-prospection: 75 tonnes of *S. lucioperca* and 1.9 tonnes of *S. glanis* in 2001 (Djemali, 2005). The *S. lucioperca* population is largely dominated by juveniles (Mili *et al*.,,2016), which reflects good conditions for reproduction and survival of young specimens. Similarly, *S. glanis* show rapid linear and somatic growths when compared with fish in their native area, for instance in the Volga delta (Orlova, 1988), possibly in relation with the abundance of nutritive resources in this body water (Boughedir, 2006).

The introduction of top-predators can affect the demography of prey species, change their composition and abundance, ultimately leading to a loss in fish diversity (Clavero and García-Berthou, 2005; Preisser *et al*., 2005). Indeed, the Algerian barb, *Luciobarbus callensis* Valenciennes, 1842, is now missing in the Sidi Salem reservoir (Djemali, 2005; Mili *et al*., 2016), while it was abundant before the introduction of *S. lucioperca* and *S. glanis,* but found to be *S. lucioperca*

---

(1) Université de Tunis El Manar, Faculté des Sciences de Tunis, Laboratoire de Biodiversité, Parasitologie et Écologie des Écosystèmes Aquatiques, 2092 Tunis, Tunisie. [houdamarine@gmail.com] [lilia.barhri@gmail.com] [oumkalthoum.hassine@gmail.com]
(2) Centre Technique d'Aquaculture, 5 rue du Sahel Montfleury, 1009 Tunis, Tunisie. [missaoui.nejiba@iresagrinet.tn] [houcine.laouar@gmail.com]
* Corresponding author [lilia.bahri@gmail.com]

Cybium 2019, 43(1): 61-69. doi: 10.26028/cybium/2019-431-006

Table I. – Origin and stock assessment of fish species in Sidi Salem reservoir. ++++: very large stock; +++: large stock; ++: limited stock; +: rare; –: missing data.

Species	Native/ Non native Losse *et al.* (1991)	Stock evaluation				
		Losse *et al.* (1991)	Djemali (2005)		Mili *et al.* (2016)	
			Ponderal abundance (%)	Instantaneous biomass (Echo-prospection)	Numerical abundance (%)	Ponderal abundance (%)
Anguilla anguilla (Linnaeus, 1758)	Native	++	–	–	–	–
Aphanius fasciatus (Valenciennes, 1821)	Native	+	–	–	–	–
Chelon ramada (Risso, 1827) and *Mugil cephalus* Linnaeus, 1758	Native	++	16	7.7	0.52	5.88
Cyprinus carpio Linnaeus, 1758	Non native	++	9	3.9	1.05	6.5
Gambusia holbrooki Girard, 1859	Non native	+	–	–	–	–
Luciobarbus callensis (Valenciennes, 1842)	Native	+++	–	–	–	–
Pseudophoxinus callensis (Guichenot, 1850)	Native	+	–	–	2.26	1.42
Sarmarutilus rubilio (Bonaparte, 1837)	Non native	++++	4	11.5	62.89	47.91
Sander lucioperca (Linnaeus, 1758)	Non native	Introduced in 1990	44	75	10.80	16.43
Scardinius erythrophthalmus (Linnaeus, 1758)	Non native	+	24	92.3	22.47	21.85
Silurus glanis Linnaeus, 1758	Non native	Introduced in 1990	3	1.9	–	–
Pomatoschistus marmoratus (Risso, 1810)	Native	++++	–	–	–	–

preferential fish prey at the time of its introduction (Losse *et al.*, 1991) and later (Toujani, 1998). Subsequent studies relate the disappearance of *L. callensis* with the predation by *S. lucioperca* (M'Hetli, 2001; Djemali, 2005). *S. lucioperca* are known to feed on cyprinid in central (Dörner *et al.*, 2007) and eastern (Didenko and Gurbyk, 2016) Europe and in Lake Seyhan, Turkey (Özyurt *et al.*, 2012), but they feed mainly on smelt, *Osmerus eperlanus* (L.) (Vehanen *et al.*, 1998; Keskinen and Marjomaki, 2004) and perch, *Perca fluviatilis* (L.) (Peltonen *et al.*, 1996) in Boreal lakes, on its congeners in Alcántara reservoir (Spain) (Pérez-Bote and Rosso, 2012), and on sand smelts, *Atherina boyeri* Risso, 1810 in Camargue (France) (Poulet, 2004).

By contrast, studies on the diet of *S. glanis* in Sidi Salem reservoir are scarce although it may exert a predatory pressure on certain species and may have contributed to the disappearance of *L. callensis*. In the single study conducted so far on the diet of *S. glanis* in the Sidi Salem reservoir, Boughedir (2006) reported a primarily piscivorous diet mainly composed of cyprinid species (*e.g. Sarmarutilus rubilio* and *Scardinius erythrophthalmus*), which meets the feeding habits known for these fishes in their natural habitat (Copp *et al.*, 2009), who showed that it mainly consumes cyprinids. A similar diet was reported for *S. lucioperca* from central (Dorner *et al.*, 2007) and eastern (Didenko and Gurbyk, 2016) Europe and from Lake Seyhan, Turkey (Özyurt *et al.*, 2012). In Sidi Salem reservoir, dietary studies of *S. lucioperca* (Losse *et al.*, 1991; Toujani, 1998; M'hetli, 2001) and *S. glanis* (Boughedir, 2006) have never been conducted at the same time, and hence it was not possible to show if their diets overlap or exclude each other. In this study, we investigate their diet in Sidi Salem reservoir according to sex, age, seasons and locations, to check and assess possible feeding overlaps between *S. lucioperca* and *S. glanis*.

MATERIAL AND METHODS

Study site

The Sidi Salem reservoir is located in northwest Tunisia (36°35'N; 9°23'E) and is the largest water reserve in the country (Fig. 1). It is built on the main watercourse of Tunisia, namely Mejerda, 70 km upstream from Tunis City. It controls a watershed of 18,250 km^2 and has an area of 4,300 ha and an average depth of 10 m. No significant variation in the physicochemical parameters (temperature, pH, dissolved oxygen) is reported between the upstream and downstream superficial waters (Ben Romdhane, 2016). Highest (up to 29.3°C) and lowest (down to 12.4°C) water temperatures are recorded in August and February, respectively; the pH ranges between 7.28 and 8.65, while dissolved oxygen concentrations vary from 5.7 to 8.6 mg/l; water salinity oscillates from 0.5 g/l to 2.1 g/l (Ben Romdhane *et al.*, 2014). Salinity variations depend on the nature and quantity of water inflow and evaporation intensity (Ben Romdhane *et al.*, 2014).

Sampling

Fish were collected monthly during one year, from May

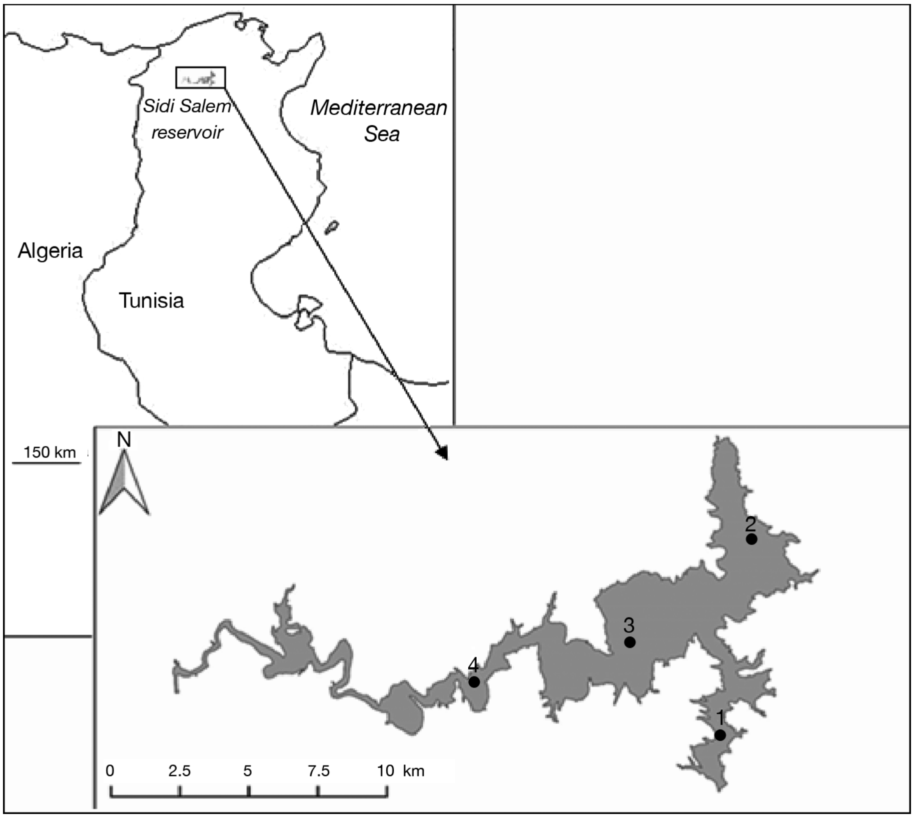

Figure 1. – Locations of the sampling stations in Sidi Salem reservoir. S1: Downstream, S2: Oued Zargha, S3: Central station, S4: Upstream.

Table II. – Biometric data of *Sander lucioperca* and *Silurus glanis* collected from Sidi Salem reservoir. N: number.

Years	Total length and weight	*Sander lucioperca*		*Silurus glanis*	
		N	Average (Min-Max)	N	Average (Min-Max)
1	LT (cm)	213	28.26 16-59	48	60.42 20.1-106
	WT (g)		210.37 28.2-2000		1874.56 65-7640
2	LT (cm)	334	33.91 14-83	114	55.51 20.7-76
	WT (g)		417.88 20.4-6020		1198.68 2839-6100

2011 to May 2012 in the station Sakira (S1), Oued Zargha (S2), and central station (S3), and from July 2012 to July 2013 in a station located upstream (S4) (Fig. 1). Sampling was performed using gillnets of different mesh sizes, *i.e.* 22 mm, 24 mm, 30 mm, 35 mm, 40 mm, 45 mm, 50 mm, 60 mm, 70 mm and 80 mm. Synthetic biometric data and global size class distribution are reported in table II and figure 2.

Individuals of *S. lucioperca* and *S. glanis,* with a total length ≥ 240 mm and 665 mm, respectively, are considered as adults (Toujani *et al*., 2000; Djait *et al*., unpubl.).

The distinction between males and females was done based on macroscopic observations of gonads in adults. Once the fish was collected, the stomach was immediately sampled and preserved in 5% buffered formalin and kept for further analyses in the laboratory. Macrophyte debris found in the gut contents of some *S. lucioperca* and *S. glanis* specimens were excluded from the analyses because their presence is most likely accidental and related to the fact that these species were predating on preys occurring on plant-covered areas within the reservoir.

Vacuity index and diet composition

The vacuity index (%VI) was measured for juveniles and adult males and females, during each season and in each sampling station. The VI reflects the frequency of feeding and it can be calculated using the equation proposed by Euzen (1987), as follows:

$$VI = (E_s / T_s) \times 100$$

where E_s is the number of empty stomachs and T_s is the total number of stomachs examined.

The qualitative analysis was undertaken through the identification of preys ingested to the lowest taxonomic level possible. As for the quantitative analysis of stomach contents, it included the following calculations:

Numerical percentage (%N): $\%N = (n_i / N_t) \times 100$

where n_i is the total number of type of prey i and N_t the total number of all preys.

Occurrence percentage (%F): $\%F = (N_{ei} / N_{et}) \times 100$

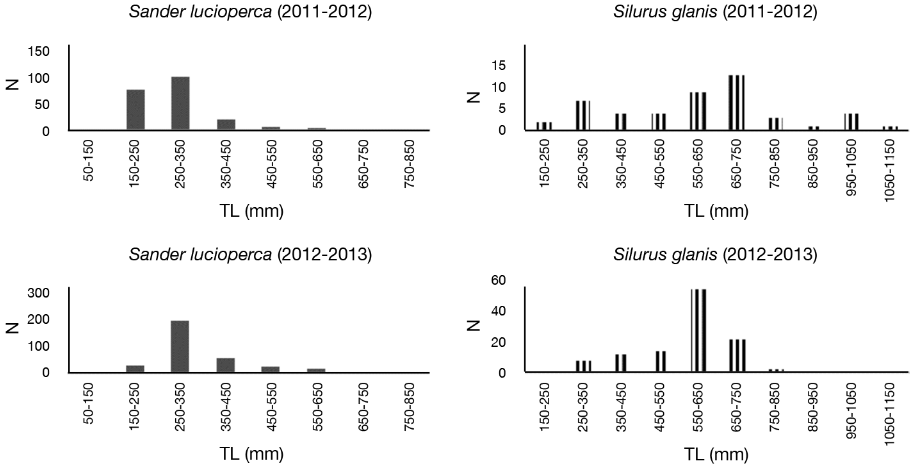

Figure 2. – Distributions of size classes of sampled *Sander lucioperca* and *Silurus glanis* from Sidi Salem reservoir. N: number of individuals.

where N_{ei} is the number of stomachs containing a type of prey i and N_{et} the total number of full stomachs examined.

Weight percentage (%W): $\%W = (W_i / W_{tp}) \times 100$

where Wi is the total weight of prey and W_{tp} the total weight of all preys (Hyslop, 1980).

The relative importance of prey taxa in each diet was determined using a standardised index of relative importance (%IRI; Cortés, 1997), which can be calculated as follows:

$$\%IRI = [IRI_i / \textstyle\sum_{i=1}^{n} IRI_i] \times 100$$

$$IRI_i = (\%N_i + \%W_i) \times \%F_i$$

where IRI*i* is the index of the relative importance of each prey *i*.

Statistical analysis

Differences in the percentage of empty stomachs, between seasons, stations, life stages and sexes were analysed using the contingency chi-square test and the chi-square test (χ^2) at a level of P value ≤ 0.05. Differences in prey compositions were analysed using Bray-Curtis dissimilarity index (Bray-Curtis). In addition, a multivariate analysis of similarities (ANOSIM) was conducted in order to test the significance of the differences between stations, seasons, sexes and life stages (juveniles/adults) for each species and between species. ANOSIM was performed using the statistical software PRIMER 6 (Clarke and Warwick, 2001).

Feeding strategy

The Costello graphical method (1990) modified by Amundsen *et al*. (1996) was used to determinate the importance of each prey category and feeding strategy for each species. Frequencies of occurrence (%F) and relative prey-specific abundances (Pi) were calculated. Pi is defined as the percentage of a prey taxon from all prey items only in those specimens in which the actual prey really occurs (Amundsen *et al*., 1996):

$$Pi = \sum S_i \sum S_{ti}^{-1} \times 100$$

where S_i is the number of stomach contents composed by prey *i* and S_{ti} is the total number of stomach contents containing prey i.

Dietary overlap

The Diet Overlap Index (α) was calculated using the prominence values of each prey according to the following formula, suggested by Schoener (1970):

$$\alpha = 1 - 0.5(\textstyle\sum_{i=1}^{n} |PV_{xi} - PV_{yi}|)$$

where n is the number of prey items, PV_{xi} is the prominence value of prey item *i* in species x and PV_{yi} is the prominence values of prey item *i* in species *y*. According to Wallace (1981), the index value varies from 0 (no diet overlap) to 1 (total diet overlap).

The Prominence Value (PV) was calculated using Hickeley *et al*. (1994) formula as follow:

$$PV = \sqrt{\%F} \times N\%$$

Niche breadth

The niche breadth of each species was estimated following on Levin's standardized index (Levins, 1968):

$$Bi = [1 / (n - 1)]\ [(1 / \textstyle\sum i\ P_{ij}^2) - 1]$$

where B_i is the standardized index of niche breadth, p_{ij} is the proportion of diet of predator i on prey j, and n is the total number of items (resources). B_i values vary from 0 (the species feed on a single item) to 1 (the species exploits available items in equal proportions).

RESULTS

We collected 709 fishes, including 162 *S. glanis* and 547 *S. lucioperca* specimens. *Silurus glanis* was only collected from S2 and S3 and we did not collect large specimens as reported previously by Boughedir (2006) and Proteau *et al*. (2008).

Vacuity index

The stomach of 296 *S. lucioperca* was empty (54%). The vacuity index did not show any difference (C = 0.08, P = 0.48) between the three stations sampled during the year 2011-2012 and combined data show no difference between seasons (C = 0.13, P = 0.24), neither between females and males (χ^2 = 0.21, P = 0.64), nor between juveniles and adults (χ^2 = 3.58, P = 0.058). Due to seasonal sample size limitations, it was only possible to test the relationship between stomach emptiness and fish during the summer and no significant difference was found in stomach emptiness with age (χ^2 = 1; P = 0.46). Considering the upstream station (S4) sampled along the year 2012-2013, there is no difference depending on season (C = 0.15; P = 0.5) or on sex (χ^2 = 0.02; P = 0.87), but there is a significant difference depending on the age of the predator (χ^2 = 6.25; P = 0.012). There is also a significant difference in the vacuity index between juveniles and adults during the winter (χ^2 = 9.95*;* P = 0.00).

The stomach of 78 *S. glanis* were empty on a total of 162 specimens (48%). There is no significant differences neither between the stations S2 and S3 (χ^2 = 1.51; P =0.46) nor between sampling season (C = 0.34, P = 0.08), sex (χ^2 = 0.17, P = 0.67) and age (χ^2 = 0.13, P = 0.71). In the upstream station (S4), there is no significant difference observed in relation with season (C = 0.10; P = 0.73), sex (χ^2 = 0.02; P = 0.88) and life stage (χ^2 = 3.84; P = 0.06).

The proportions of empty stomachs do not differ significantly between *S. glanis* and *S. lucioperca*, whenever we take into account sampling station, sampling season, sex and specimen age.

Diet composition

The analysis of the stomach contents of *S. lucioperca* revealed the existence of three types of prey: teleost fishes, crustaceans and insect larvae. Fish preys were prevalent component in terms of abundance, occurrence and weight (IRI = 98%; Tab. III). They include *Sarmarutilus rubilio*, *Scardinius erythrophthalmus*, *S. lucioperca* juveniles and unidentified fish remains. In most cases, it was not possible to distinguish between the two cyprinids, *Sarmarutilus rubilio* and *Scardinius erythrophthalmus*, and hence the quantitative parameters were calculated for cyprinids as a whole (Tab. III). Crustacean preys belong to a single species, *Atyaephyra desmaresti*, and display a low IRI (IRI = 1.6%). The IRI index of insect larvae was found to be even lower (IRI = 0.5%). During 2011-2012, there is no significant difference in terms of station (ANOSIM %IRI: R = 0.10; P = 0.1), season (ANOSIM %IRI: R = 0.084; P = 0.10), sex (ANOSIM %IRI: R = 0.001; P = 0.28) and age (ANOSIM %IRI: R = 0.018; P = 0.23). Similar observations are done along 2012-2013 in S4.

Only two prey categories were identified for *S. glanis*: teleost fishes and crustaceans (Tab. III). The cyprinids *Sarmarutilus rubilio* and *Scardinius erythrophthalmus,* unidentified fish remains, and juveniles of *S. glanis* largely prevailed in terms of occurrence, weight and abundance (IRI = 99.9%), while only a few *A. desmaresti* was ingested (IRI = 0.1%).

Table III. – Values of dietary indexes of several preys. %N: Numerical percentage; %W: Weight percentage; %F: Occurrence percentage; %IRI: Index of Relative Importance.

	Sander lucioperca				*Silurus glanis*				χ^2 test	
	%F	%N	%W	%IRI	%F	%N	%W	%IRI	$\chi2$	P
Teleost fish	86.45	76.96	99.15	98	72.29	96.67	99.69	99.9	0.36	0.54
Unidentified remains of teleost fish	60.56	46.32	65.43	61.53	50.6	54.17	76.81	53.87	0.18	0.67
Cyprinids (*Sarmarutilus rubilio* and *Scardinius erythrophthalmus*)	13.94	11.03	28.78	3.49	16.87	26.67	19.94	7.95	1.14	0.28
Sander lucioperca	2.39	1.72	2.32	0.06	0.00	0.00	0.00	0.00		
Silurus glanis	0	0	0	0	2.41	2.50	0.4	0.05		
Crustacean: *Atyaephyra desmaresti*	15.94	14.71	0.66	1.6	4.82	3.33	0.31	0.1	4.78	0.02
Insect larvae	8.76	8.33	0.19	0.5	0.00	0.00	0.00			

Table IV. – Values of average dissimilarity between *Sander lucioperca* and *Silurus glanis*. F: female; M: male

	S. lucioperca vs. *S. glanis* diet comparisons														
	First year								Second year						
	Station		Season				Sex		Station	Season				Sex	
Samples	Oued Zargha station	Central station	Spring	Winter	Autumn	Summer	F	M	Upstream	Autumn	Summer	Spring	Winter	F	M
Average dissimilarity (%)	31.71	18.96	0	6.24	13	38.76	31.55	22.34	18.56	11.91	14.18	26.48	13.64	12.91	20.57

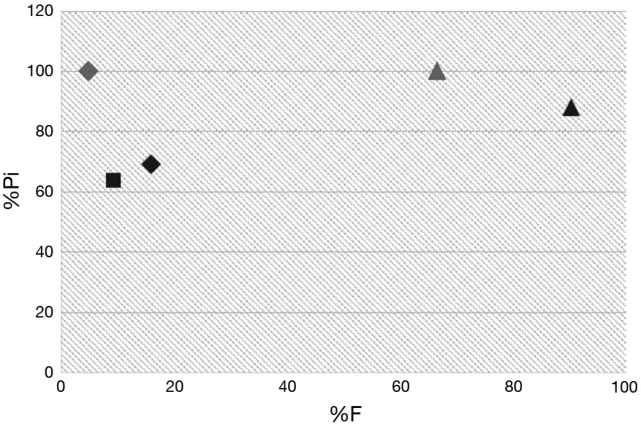

Figure 3. – Modified Costello graphs (plots of prey-specific abundance (%Pi) and frequency of occurrence (%F)) showing the feeding patterns of *Sander lucioperca* and *Silurus glanis*, in Sidi Salem reservoir. Preys of *Sander lucioperca* are in dark and those of *Silurus glanis* in grey. ◆: *A desmarti*; ▲: Teleost Fish; ■: Insects larvae.

The diet does not vary along 2011-2012 in relation with sampling station (ANOSIM %IRI: R = –0.067, P = 1), season (ANOSIM %IRI: R = –0.056, P = 0.73), sex (ANOSIM %IRI: R = -0.057, P = 1) and life stage (ANOSIM %IRI: R = –0.060, P = 1). During 2012-2013, the diet of *S. glanis* in S4 does not vary neither in any aspect.

S. glanis and *S. lucioperca* have the same diet with respect to sampling station, sampling season and sex (Tab. IV).

Diet overlap and niche breadth

The diets of *S. glanis* and *S. lucioperca* show a great overlap ($\alpha_{\text{overall}} = 0.85$) during the 2011-2012, and also in details along seasons ($\alpha_{\text{autumn}} = 0.88$; $\alpha_{\text{summer}} = 0.83$; $\alpha_{\text{spring}} = 0.91$), in each sampling station ($\alpha_{\text{wadizargha}} = 0{,}87$; $\alpha_{\text{middle}} = 0.8$) and according to sex ($\alpha_{\text{male}} = 0.86$; $\alpha_{\text{female}} = 0.92$). The overlap was also great in S4 during 2012-2013 ($\alpha_{\text{overall}} = 0.90$), and also with respect to sex ($\alpha_{\text{female}} = 0.82$; $\alpha_{\text{male}} = 0.87$) and season ($\alpha_{\text{Autumn}} = 0.88$; $\alpha_{\text{Summer}} = 0.85$; $\alpha_{\text{Winter}} = 0.81$; $\alpha_{\text{Spring}} = 0.81$). Levins index B, estimated for both species, was equal to 0. Thus, the trophic niche of these species is very narrow. Costello graph (Costello, 1990), modified by Amundsen *et al.* (1996), illustrates well how much teleost fishes are the dominant diet component, in terms of both prey specific abundance (% Pi) and prey occurrence frequency (%F) for both species (Fig. 3), while crustaceans and insect larvae appeared to be only consumed by few individuals.

DISCUSSION

This is the first study comparing the dietary habits of *S. lucioperca* and *S. glanis* from Sidi Salem reservoir. The proportion of *S. glanis* with an empty stomach (48%) is higher than previously recorded in the same reservoir (VI = 25%; Boughedir, 2006), but close to that reported in Hirfanli reservoir in Turkey (VI = 44%; Dogan Bora and Gul, 2004). However, the low percentage measured previously by Boughedir (2006) may be explained by the reduced sample size (72 specimens) and the limited temporal extant of the study (8 months). It has been reported that the intensity of food intake decreases when prey abundance and temperature decrease (Omarov and Popova, 1985; Wysujack and Mehner, 2005; Copp *et al.*, 2009). However, in our study we do not notice any significant change along seasons in the proportion of empty stomachs in Sidi Salem reservoir; there seems to be no influence of water temperature on predatory fish diet.

A diversified dietary spectra including nematodes, rodents, cestodes, scyphozoans, crustaceans, annelids, insects, molluscs, plants, birds, frogs, crabs, leeches and fishes have been described in other water reservoir for *S. glanis* (Copp *et al.*, 2009; Alp, 2017). Although previous works on *S. glanis* in Sidi Salem reservoir reported a dietary spectrum including also water rat, frogs and insects, alongside with fishes and crustaceans (Boughedir, 2006), the present work showed that the dietary spectrum of the same species is limited to only three fish species, *Sarmarutilus rubilio*, *Scardinius erythrophthalmus, S. glanis* juveniles and the crustacean *A. desmartii*. This can be explained by the fact that the study of Boughedir (2006) deals with large-sized adults (maximum 188 cm) compared to ours (maximum 106 cm), so that *S. glanis* becomes opportunistic in Sidi Salem reservoir at sizes exceeding 106 cm. However, the water rats were only found in the stomachs of *S. glanis* caught during a single fishing near the dam building immediately after a flood; so in spite of increase of the variability in the dietary spectra with growth, *S. glanis* is thought to be essentially piscivorous and that cyprinids are its preferential preys, while water mice and frogs are considered as occasional preys (Boughedir, 2006).

The fact that *Sarmarutilus rubilio* and *Scardinius erythrophthalmus* are the main preys of *S. glanis* is to relate with the fact that they are the most abundant fishes in Sidi Salem reservoir (Mili *et al.*, 2016). Within this context, Djemali (2005) reported that the environmental conditions in Sidi Salem reservoir are very favourable for the reproduction, recruitment and growth of these forage fishes. It is well known that *S. glanis* has a limited movement pattern and strong site fidelity (Carol *et al.*, 2007; Slavík and Horký, 2009; Brevé *et al.*, 2014). This behaviour can explain why *S. glanis* dietary spectrum is dominated by the most abundant fish species (Omarov and Popova, 1985; Copp *et al.*, 2009; Alp, 2017). Similar findings were observed in Menzelet Reservoir in Turkey, where *S. glanis* was found to feed mainly on *Alburnus kotschyi* Steindachner 1863, which is the most important prey (Alp, 2017).

Regarding *S. lucioperca*, the VI calculated in the present study (54%) is close to that previously reported in the same reservoir (M'Hetli, 2001: 56%). Across seasons, it does not vary significantly with the exception of an increase of emptiness in adults during winter. This result was expected since the spawning period of *S. lucioperca* occurs in winter (Toujani, 1998; Toujani *et al*., 2000) and because *S. lucioperca* reduce their food consumption during the reproduction period (M'Hetli, 2001). This phenomenon was yet reported in Seyhan reservoir (in Turkey), where feeding intensity of *S. lucioperca* was related to the reproduction period (Özyurt *et al*., 2012).

Similarly to *S. glanis*, the diet composition of *S. lucioperca* juveniles and adults is largely dominated by teleost fishes, and includes a few crustacean and insect larvae. This is in discordance with a previous study that evidenced diet changes between juveniles, that mainly feed on *A. dersmarti,* and strictly piscivorous adults (Toujani 1998). Similarly, M'Hetli (2001) reported ontogenetic shifts in *S. lucioperca* diet, with cladocers for 50 mm-long individuals, *A. desmarti* and cladocers for 50-100 mm-long individuals, insects and *A. desmarti* for 100-200 mm-long fishes and fish for individuals with size exceeding 200 mm. To explain the dominance of fish preys in the diet of juveniles in Sidi Salem reservoir between 2011 and 2013, we assume that this is due to the seeding of a very large number of mullet fries intentionally introduced, every year, since 2000, including about 2 million mullet fries in 2010-2011, 2.38 million in 2011-2012 and 1.09 million in 2012-2013 (Technical Centre of Aquaculture, 2010, 2012, 2013). Among the introduced mullet species, *Mugil cephalus* Linnaeus, 1758 and *Chelon ramada* (Risso, 1827) became well-established in the Sidi Salem reservoir (Djemali, 2005; Mili *et al*., 2016). These two latter species contributed to 18 and 30%, respectively, of the total catches of Sidi Salem reservoir between 2008 and 2013 (DGPA, 2018). Thus, it might be possible that these introduced mullet fries have become among the main prey items of *S. lucioperca* juveniles along the last decades. A similar change in *S. lucioperca* diet was also recorded in Kiel Canal (North Germany), following the introduction of the round goby, *Noegobius melanostomus* (Pallas, 1814) (Hempel *et al*., 2016). In addition, we suggest that this diet shift in *S. lucioperca* juveniles from previously-preferred prey items to mullet fries might be also caused by a possible decline of insects and/or *A. desmarti* stocks from Sidi Salem reservoir. This hypothesis cannot be verified because of the lack of data on insect and *A. desmarti* stocks in Sidi Salem reservoir.

Similarly to *S. glanis*, *S. lucioperca* was found to feed mainly on *Sarmarutilus rubilio* and *Scardinius erythrophthalmus*, which are the most abundant fish species in Sidi Salem reservoir (Mili *et al*., 2016). Other studies showed that *S. lucioperca* is piscivorous with a diet changing with food seasonal abundance (Popova and Sytina, 1977). Various studies reported that the dietary spectrum of *S. lucioperca* can be composed of frogs, reptiles, invertebrates (*e.g.* insects, malacostracea, clitellata and gastropod), and several families of fishes including cyprinids (Yilmaz and Ablak, 2003; Balik *et al.,* 2006; Kangur *et al.,* 2007; Özyurt *et al*., 2012; Pérez-Bote and Roso, 2012; Didenko and Gurbyk, 2016). However, we found that the dietary spectrum of *S. lucioperca* in Sidi Salem is narrow (limited to 5 prey types only), which is due most likely to the low fish diversity in this reservoir (Mili *et al*., 2016).

A very low percentage of cannibalism in both predator species was found in the present study. According to Campbell (1992) and Mihalik (1995), the probability of cannibalism decreases when alternative preys are very abundant. This low percentage is thus due to the abundance of preys (Mili *et al*., 2016) with a suitable size.

Despite the fact that *S. lucioperca* is an active predator (Vehanen and Lahti, 2003) while *S. glanis* behaviour is characterized by relatively few movements (Brevé *et al*., 2014), their diet show a significant overlap in Sidi Salem reservoir since they feed on the most abundant fish preys. Similar findings were recorded in the Kaniv reservoir in Ukraine (Didenko and Gurbyk, 2016). Moreover, *S. glanis* have caused the extinction of some species such as *Rutilus aula* (Bonaparte, 1841) and *Tinca tinca* (Linnaeus, 1758), as well as a decline in the abundance and biomass of *Scardinus erythrophthalmus* and *Alburnus arborella* (Bonaparte, 1841) from the lower portion of the Po River basin (Castaldelli *et al*., 2013). Similarly, *S. lucioperca* was considered as the main agent behind the depletion of native fish stocks from several Turkish lakes (Ribeiro and Leunda, 2012) and of the endemic species *Alburnus neretvae,* 30 years after the first introduction of *S. lucioperca* in Ramski and Jablanički reservoirs (Bosnia and Herzegovina, Croatia) (Pavlicevic *et al*., 2015). In the Turkish lake of Egirdir also, most native fish have disappeared due to *S. lucioperca* predation (Yerli *et al*., 2013). In Sidi Salem reservoir, the almost disappearance of *L. callensis* is currently attributed to *S. lucioperca*, however and despite the lower abundance of *S. glanis*, we cannot exclude that this fish is also partly responsible because of the large overlap of the diets between these two predators.

The findings of the present study are worth using in any future fishery management plans and biodiversity preservation strategies that could be adopted in Sidi Salem reservoir. Future decisions to introduce new species should take into account the seeding of mullet fries and the loss of native biodiversity from this freshwater system.

Acknowledgements. – This study is the result of a collaborative work between the Technical Centre of Aquaculture and the University of Tunis El Manar. The authors express their sincere thanks to the journal Editor Olga Otero, the Assistant Editor Elise Dufour and two anonymous reviewers who helped to improve the quality of the manuscript through their constructive comments, suggestions and English revision. We are also grateful to Lotfi Rabaoui for revising and editing the English manuscript.

REFERENCES

ALP A., 2017. – Diet shift and prey selection of the native European Catfish, *Silurus glanis*, in a Turkish reservoir. *Limnol. Fish*, 3(1): 15-23.

AMUNDSEN P.A., GABLER H.M. & STALDVIK F.J., 1996. – A new approach to graphical analysis of feeding strategy from stomach content data – Modification of the Costello (1990) method. *J. Fish. Biol.*, 48: 607-614.

BALIK I., ÇUBUK H., KARASAHI B., ÖZKOK R., UYSAL R. & ALP A., 2006. – Food and feeding habits of the pikeperch, *Sander lucioperca* (Linnaeus, 1758), population from Lake Egirdir (Turkey). *Turk. J. Zool.*, 30: 19-26.

BEN ROMDHANE S., 2016. – Étude de la distribution et de la dynamique des communautés microbiennes (Virus, bactéries et phytoplancton) dans la retenue du barrage de Sidi Salem. Évolution de la salubrité du plan d'eau. Thèse de Doctorat, 233 p. Univ. Tunis II, Tunisie.

BEN ROMDHANE S., ELBOUR M., HAMZA A. & KRAIEM M.M., 2014. – Étude comparative par épifluorescence et cytométrie en flux des communautés bactériennes des eaux de la retenue du barrage Sidi Salem (Tunisie septentrionale). *Bull. Inst. Natl. Sci. Tech. Mer Salammbô*, 41: 121-132.

BOUGHEDIR W., 2006. – Étude de l'écobiologie du Silure (*Silurus glanis*, L. 1978) dans la retenue du barrage de Sidi Salem. Mémoire de Mastère, 81 p. Univ. Carthage, Tunisie.

BREVÉ N.W.P., VERSPUI R., DE LAAK G.A.J., BENDALL B., BREUKELAAR A.W. & SPIERTS I.L.Y., 2014. – Explicit site fidelity of European catfish (*Silurus glanis*, L., 1758) to manmade habitat in the River Meuse, Netherlands. *J. Appl. Ichthyol.*, 30: 472-478.

CAMPBELL R.N.B., 1992. – Food of an introduced population of pikeperch (*Stizostedion lucioperca*) in Lake Egirdir, Turkey. *Aquacult. Fish. Manage.*, 23: 71-85.

CAROL J., ZAMORA L. & GARCIA-BERTHOU E., 2007. – Preliminary telemetry data on the patterns and habitat use of European catfish (*Silurus glanis*) in a reservoir of the River Ebro, Spain. *Ecol. Freshw. Fish.*, 16: 450-456.

CASTALDELLI G., PLUCHINOTTA A., MILARDI M., LANZONI M., GIARI L., ROSSI R. & FANO E.A., 2013. – Introduction of exotic fish species and decline of native species in the lower Po basin, north-eastern Italy. *Aquat. Conserv.: Mar. Freshw. Ecosyst.*, 52: 567-580.

CLARKE K.R. & WARWICK R.M., 2001. – Change in Marine Communities: an Approach to Statistical Analysis and Interpretation. 2nd Edit. PRIMER-E: Plymouth.

CLAVERO M. & GARCÍA-BERTHOU E., 2005. – Invasive species are a leading cause of animal extinctions. *Trends Ecol. Evol.*, 20: 110.

COPP G.H., BRITTON R.J., CUCHEROUSSET J., GARCIA-BERTHOU E., KIRK R. PEELER E. & STAKENAS S., 2009. – Voracious invader or benign feline? A review of the environmental biology of European catfish *Silurus glanis* in its native and introduced ranges. *Fish. Fish.*, 10: 252-282.

CORTÉS E., 1997. – A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes. *Can. J. Fish. Aquat. Sci.*, 54: 726-738.

COSTELLO M.J., 1990. – Predator feeding strategy and prey importance: a new graphical analysis. *J. Fish. Biol.*, 36: 261-263.

CTA, 2010. – Rapport annuel 2009. Rapport annuel des activités du Centre Technique d'Aquaculture de 2009. CTA Tunisie, 38 p.

CTA, 2012. – Rapport technique de l'ensemencement des barrages 2011-2012. CTA Tunisie, 8 p.

CTA, 2013. – Rapport technique de l'ensemencement des barrages 2012-2013. CTA Tunisie, 8 p.

DGPA, 2018. – Annuaire des statistiques de pêche de la Direction Générale de la Pêche et de l'Aquaculture. Tunis: Direction Générale de la pêche et de l'Aquaculture.

DIDENKO A.V. & GURBYK A.B., 2016. – Spring diet and trophic relationships between piscivorous fishes in Kaniv Reservoir (Ukraine). *Folia Zool.*, 65(1): 15-26.

DJEMALI I., 2005. – Évaluation de la biomasse piscicole dans les plans d'eau douce tunisiens : approches analytique et acoustique. Thèse de Doctorat, 218 p. Univ. Carthage, Tunisie.

DOĞAN BORA N. & GÜL A., 2004. – Feeding biology of *Silurus glanis* (L., 1758) living in Hirfanli Dam Lake *Turk. J. Vet. Anim. Sci.*, 28(3): 471-479.

DÖRNER H., HULSMANN S., HOLKER F., SKOV C. & WAGNER A., 2007. – Size-dependent predator-prey relationships between pikeperch and their prey fish. *Ecol. Freshw. Fish.*, 16: 307–314.

EUZEN O., 1987. – Food habits and diet composition of some fishes of Kuwait. *Kuwait Bull. Mar. Sci.*, 9: 65-86.

HEMPEL M., NEUKAMM R. & THIEL R., 2016. – Effects of introduced round goby (*Neogobius melanostomus*) on diet composition and growth of pike-perch (*Sander lucioperca*), a main predator in European brackish waters. *Aquat. Invasions*, 11(2): 167-178.

HICKELEY P., NORTH R., MUCHIRI S.M. & HARPER D.M., 1994. – The diet of largemouth bass, *Micropterus salmoides*, in Lake Navaisha, Kenia. *J. Fish. Biol.*, 44: 607-619.

HYSLOP E.J., 1980. – Stomach contents analysis: a review of methods and their application. *Fish Biol.*, 17: 411-429.

KANGUR P., KANGUR A. & KANGUR K., 2007. – Dietary importance of various prey fishes for pikeperch *Sander lucioperca* (L.) in large shallow Lake Võrtsjärv (Estonia). *Proc. Estonian Acad. Sci.: Biol. Ecol.*, 56: 154-167.

KESKINEN T. & MARJOMAKI T.J., 2004. – Diet and prey size spectrum of pikeperch in lakes in central Finland. *J. Fish Biol.*, 65: 1147-1153.

LEVINS R., 1968. – Evolution in Changing Environments: Some Theoretical Exploitations. 3rd Edit., 121 p. Princeton University Press, Princeton.

LOSSE G.F., NAU W. & WINTER M., 1991. – Le développement de la pêche en eau douce dans le nord de la Tunisie. Projet de coopération technique tuniso-allemande : utilisation de barrages pour la pisciculture, Commissariat général à la Pêche (CGP)/ Gesellschaft für Technische Zusammenarbeit (GTZ), 418 p.

M'HETLI M., 2001. – Le sandre *Stizostedion lucioperca* (Linnaeus, 1758) poisson allochtone : l'étude biologique et essai d'optimisation des critères de l'élevage. Thèse de Doctorat, 170 p. Univ. Tunis II, Tunisie.

MIHALIK J., 1995. – Der Wels. Die Neue Brehm-Bucherei. 2nd Edit., 71 p. Westarp Wissenschaften, Magdeburg.

MILI S., ENNOURI R., LAOUAR H., BEN ROMDHANE N. & MISSAOUI H., 2016. – Étude des peuplements piscicoles de la retenue du barrage de Sidi Salem. *J. New. Sci.*, 27(1): 1454-1465.

OMAROV O.P. & POPOVA O.A., 1985. – Feeding behavior of pike, *Esox lucius*, and catfish, *Silurus glanis*, in the Arakum Reservoirs of Dagestan. *J. Ichthyol.*, 25(1): 25-36.

ORLOVA E.L., 1988. – Peculiarities of growth and maturation of the catfish, *Silurus glanis*, in the Volga Delta under regulated flow conditions. *J. Ichthyol.*, 16(1): 75-87.

ÖZYURT C.R., MAVRUK S. & KIYAGA V.B., 2012. – Effects of predator size and gonad maturation on food preference and feeding intensity of *Sander lucioperca* (Linnaeus, 1758). *Turk. J. Fish. Aquat. Sci.*, 12: 315-322.

PAVLICEVIC J., GLAMUZINA L., CONIDES A., SAVIC N., ROZIC I., KLAOUDATOS D. KAZIC A. & GLAMUZINA B., 2015. – Pikeperch *Sander lucioperca* invasion in the Neretva River Watershed (Bosnia and Herzegovina, Croatia) after alteration of river flow. *River. Res. Applic.*, 32: 967-974.

PELTONEN H., RITA H. & RUUKJÄRVI J., 1996. – Diet and Prey selection of pikeperch (*Stizostedion lucioperca* (L)) in lake Vesijarvi analysed with a logit model. *Ann. Zool. Fennici*, 33: 481-487.

PÉREZ-BOTE J.L. & ROSO R., 2012. – Diet of the introduced pikeperch *Sander lucioperca* (L.) (Osteichthyes, Percidae) in a recent colonised reservoir in south-western Iberian Peninsula. *Ital. J. Zool.*, 79(4): 617-626.

POPOVA O. & SYTINA L., 1977. – Food and feeding relations of Eurasian perch (*Perca fluviatilis*) and pikeperch (*Stizostedion lucioperca*) in various waters in the USSR. *Fish. Res. Bd. Can.*, 34: 1559-1570.

POULET N., 2004. – Le sandre (*Sander lucioperca* (L.)) : biologie, comportement et dynamique des populations en Camargue (Bouches du Rhône, France). Thèse de Doctorat, 301 p. Univ. Paul Sabatier, Toulouse III, France.

PREISSER E.L., BOLNICK D.I. & BENARD M.F., 2005. – Scared to death? The effects of intimidation and consumption in predator-prey interaction. *Ecology*, 86: 501-509.

PROTEAU J.P., SCHLUMBERGER O. & ÉLIE P., 2008. – Le Silure glane : Biologie, Écologie, Élevage. 226 p. Paris: Éditions Quae.

RIBEIRO F. & LEUNDA P.M., 2012. – Non-native fish impacts on Mediterranean freshwater ecosystems: current knowledge and research needs. *Fish. Manage. Ecol.,* 19: 142-156.

SCHOENER T.W., 1970. – Non-synchronous spatial overlap of lizard in patchy habitats. *Ecology*, 51: 408-418.

SLAVÍK O. & HORKÝ P., 2009. – When fish meet fish as determined by biotelemetry. *Ecol. Freshw. Fish.*, 18: 501-506.

TOUJANI R., 1998. – Le sandre *(Stizostedion lucioperca)* de la retenue de Sidi Salem (Tunisie) : biologie et dynamique de population. Thèse de doctorat, 189 p. Univ. Claude Bernard Lyon I, France.

TOUJANI R., MISSAOUI H & ROMDHANE M.H., 2000. – Cycle sexuel des femelles de sandre *Stizostedion lucioperca* (L. 1758) (Pisces, Percidae) dans la retenue de barrage de Sidi Salem (Tunisie). *Bull. Inst. Natl. Sci. Tech. Mer Salammbô.*, 27 : 85-96

VEHANEN T. & LAHTI M., 2003. – Movements and habitat use by pikeperch *(Stizostedion luciopercs*a (L.) in a hydropeaking reservoir. *Ecol. Freshw. Fish.*, 12: 203-215.

VEHANEN T., HYVARINEN P. & HUUSKO A., 1998. – Food consumption and prey orientation of piscivorous brown trout (*Salmo trutta*) and pikeperch (*Stizostedion lucioperca*) in a large regulated lake. *J. Appl. Ichthyol.*, 14: 15-22.

WALLACE R.K., 1981. – An assessment of diet-overlap indexes. *Trans. Am. Fish. Soc.*, 110: 72-76.

WYSUJACK K. & MEHNER T., 2005. – Can feeding of European catfish prevent cyprinids from reaching a size refuge? *Ecol. Freshw. Fish.*, 14: 87-95.

WYSUJACK K., LAUDE U., KASPRZAK P. & MEHNER T., 2002. – Management of a pikeperch stock in a long-term biomanipulated stratified lake: efficient predation vs. low recruitment. *Hydrobiologia.*, 479: 169-180.

YERLI S.V., ALP A., YEĞEN V., UYSAL R., YAĞCI M.A & BALIK I., 2013. – Evaluation of the ecological and economical results of the introduced alien fish species in Lake Eğirdir, Turkey. *Turk. J. Fish. Aquat. Sci.*, 13: 795-809.

YILMAZ M. & ABLAK Ö., 2003. – The Feeding behavior of pikeperch (*Sander lucioperca* (L., 1758)) living in Hirfanli Dam Lake. *Turk. J. Vet. Anim. Sci.*, 27: 1159-1165.